# Generic Verification Protocol for Induction Mixers Used for High Rate Disinfection of Wet Weather Flows

## Draft 3.4

**For**

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# 1 Introduction

## 1.1 Purpose

The purpose of this document is to establish a protocol for the verification of induction mixers intended for use in the chemical disinfection of wet weather flows, such as combined sewer overflows and sanitary sewer overflows. The protocol established here will serve as the basis for verification of commercially-available induction mixers under the Environmental Technology Verification (ETV) Program of the United States Environmental Protection Agency (EPA). This protocol describes the steps to be followed to ensure that verification is carried out in a consistent and objective manner that assesses the relevant performance characteristics of an induction mixer. It describes, in general terms, the process of selecting and documenting the verification tests to be conducted, and outlines the methodology to be employed. The protocol provides guidelines for the preparation of a Verification Test Plan that is specific to a given mixer and the organization conducting the test. Guidance is also provided on the execution of testing and data reduction, analysis and reporting.

## 1.2 Scope

This Protocol is intended to apply to induction mixers with a motor speed greater than 3,000 rpm and which are designed for submerged service in wet weather flows such as combined sewer overflows (CSO) and sanitary sewer overflows (SSO).

## 1.3 The ETV Program and the Wet Weather Flow Technologies Pilot

The Environmental Technology Verification (ETV) program was established to promote the marketplace acceptance of commercial-ready environmental technologies. The purpose is to provide credible third-party performance assessments of environmental technologies so that users, developers, regulators, and consultants can make informed decisions about such technologies. ETV is not an approval process, but rather provides a quantitative assessment of technology performance as dtermined in accordance with an established test protocol . Twelve ETV “Pilots” were established to verify innovative technologies covering the range of environmental media. Each Pilot is administered through a cooperative agreement between EPA and a Verification Partner Organization.

The Wet Weather Flow Technologies Pilot was established to verify commercially available technologies used in the control and abatement of urban storm water runoff, combined sewer overflows and sanitary sewer overflows. NSF International (NSF) is the verification partner organization on the Wet Weather Flow Technologies Pilot and administers the WWF Pilot in cooperation with the Urban Watershed Management Branch of the US EPA's National Risk Management Research Laboratory.

A Stakeholder Advisory Group (SAG) was formed to assist NSF and EPA in establishing priorities for the verification of wet weather flow technologies. The SAG consists of technology vendors, state and federal regulatory and permitting officials, technology users (POTWs and other municipal government staff), and technology enablers (e.g., consulting firms and universities) with an interest in the assessment and abatement of the impacts of wet weather flows. The SAG identified high-rate disinfection technologies as a priority for verification given their potential role in abating the frequency and extent of pathogen discharges to surface waters associated with combined sewer overflows.

The Technology Panel on High Rate Disinfection was established to guide the development of a protocol for the verification of high rate disinfection technologies, including induction mixers. NSF contracted with Moffa & Associates to develop a draft verification protocol.

### 1.4 Technology Applications and Description

Experience has shown that the long disinfection contact time required for conventional wastewater treatment is not appropriate for the disinfection of CSO due to the infrequent peak flow rates that would require large tankage. However, disinfection of CSO can be achieved with less contact time by providing an increased disinfection dosage and intense mixing. Mechanical mixers at one or more disinfectant locations can accomplish such mixing.

The induction type mixer produces relatively intense mixing due to the impeller speed. The induction mixer was originally designed to inject chemicals into process water. The fundamental principal is to rotate an impeller at a sufficient rpm as to cause a vacuum behind the impeller. This vacuum pressure is then used to draw chemicals to the impeller. Induction mixing is unique in that it blasts the wastewater with a fine spray of chemical disinfectant. This provides an almost instantaneous dispersion due to the high rotation of the impeller. Such dispersion allows the most effective forms of the chemical disinfectant to react with bacteria, which greatly improves the disinfection process. However, there are still some questions regarding the appropriate size and effectiveness of such mixers. Therefore the ETV program will focus on induction mixers and verifying volume of water affected by the mixer.

Using an induction mixer for CSO disinfection has proven to be economical (Moffa & Associates, 1997). Because CSO facilities operate intermittently, reducing capital costs by possibly incurring higher operation and maintenance is economically viable. Using high-rate disinfection with induction mixing reduces contact times from 15-30 minutes to 5 minutes (Moffa & Associates, 1997). The reduced construction cost for the smaller basins generally offset any higher operation and maintenance costs.

High rate disinfection is governed by the relationship:

$$\text{Kill} = \text{Fn}\ (c \times G \times t)$$

Where: c = concentration of disinfectant

G = mixing intensity

t = time of contact (within a contained volume)

The mixing intensity is a function of the power imparted into a volume of water. Mean velocity gradient (G) is a measure of mixing intensity and has become an industry standard for representing the fluid mechanics of mixing. It is directly related to the total shear per unit volume per unit of time. The G number gives an indication of turbulence as it relates to head loss, which in turn relates to mixing (White, 1992). The velocity gradient is therefore a parameter of disinfection efficiency. G can be expressed by the following equation:

$$G = (P/ u*V)^{½}$$

Where P is the power requirement, V is volume of affected process water, and u is the absolute fluid viscosity. The mean velocity gradient for a typical well designed diffuser grid system is on the order of 200-500/sec. G.C. White used to believe that the G number should be approximately 1,000/sec for superior mixing. Some of White's more recent research indicates that a G number between 700 and 1.000/sec may be appropriate regardless of disinfection requirements. (White, 1992).

Collins and Kruse (EPA-670/2-73-077) have demonstrated the influence of mixing intensity on bacterial kills and formation of chloramines with $Cl_2$. When chlorine or hypochlorite is added to wastewater containing ammonia, the free chlorine will react to form chloramines. The rate of bactericidal efficacy of chloramines is significantly less than that of free chlorine. It is theorized that by instantaneously dispersing hypochlorite in the wastewater stream using high-rate mixing, more of the organisms in the wastewater can come into contact with chlorine in its free form prior to the formation of chloramines and, therefore, result in greater kills.

In the past, researchers have related bacterial reductions to Gt. This relationship holds true when the mixing devices are operated in a mixing chamber of fixed size. This relationship does not hold true when the mixing devices are operated in an open channel, allowing the mixing zone volume to change as a result of horsepower (Hp) and channel geometry. Alternatively, the extent of mixing can be directly measured by chemical concentrations at defined locations downstream of the mixer.

### 1.5 Experimental Objective

A manufacturer of an induction- type mixer may make claims about the mixing capabilities of its product and its ability to provide rapid, uniform chemical transfer resulting in reduction or elimination of chemical breakout and stratification. Since these claims are subjective, often the manufacturers will provide a G factor for a specific induction mixer application. However there is not a standard method or approach used for calculating this G factor. As presented in the previous section, G is a function of the mixer power and the volume of the affected process water. The power and viscosity variables are standard and therefore the manufacturers use consistent values, but each manufacturer defines the volume variable differently. As a result each manufacturer may claim a different G, based on their definition of volume. Currently, there is no standard for representing volume.

In response to the manufacturer's claims regarding "rapid uniform chemical transfer" and the inconsistencies in calculating G, this ETV protocol establishes a method for the determining the volume of process water affected by the induction mixer. The testing will be performed in a hydraulic laboratory setting. During the verification testing, the high-rate induction mixers will be operated as though they were installed in a disinfection facility. However, instead of mixing a chemical disinfectant into the process water, a dye or conservative tracer chemical will be used in a clean water matrix. The dye or conservative tracer chemical will allow the researcher to observe the extent of mixing provided by the high-rate induction mixers.

The objective of this ETV protocol is to evaluate the effectiveness of induction mixers based on their ability to transfer chemicals into the process water. The volume of water affected by the mixer (i.e. mixing zone) will define the effectiveness of that particular mixer. The velocity of the process water has the greatest influence on the induction mixer's ability to transfer chemicals into the water. This ETV protocol establishes a method for verifying the performance of induction mixers over a range of flow velocities. This range of velocities will represent the typical range of flow conditions at wet-weather treatment facilities.

### 1.6 Technical Approach

The general approach will be to define the mixing zone volume by introducing a dye or conservative tracer chemical at the point of the impeller and measuring the dye or tracer concentration around and just downstream the impeller. The measured dye or tracer concentrations will then be used to define the volume of water affected by the mixer. This approach will be performed for a combination of different flow velocities and mixing times for each induction mixer tested.

The transfer of chemicals into the process water is a function of mechanical dispersion and molecular diffusion. Mechanical dispersion is a function of the induction mixer and the velocity of the process water. Molecular diffusion is a function of chemicals moving from high concentration to low concentration. In the case of induction mixers, the mechanical dispersion is several orders of magnitude greater than molecular diffusion, and therefore molecular diffusion can be disregarded. Some inference between the mechanical dispersion from the induction mixer and the process water velocity will be made based on the tests at different velocities.

### 1.7 Verification Process

The process of verification of induction mixers under the ETV Program consists of three primary phases as described below:

Planning – The planning phase involves establishing and documenting the procedures to be followed during the verification of a specific induction mixer, including identifying the testing laboratory and personnel responsible for performance and oversight of the testing. The planning phase culminates in the preparation of a product-specific Verification Test Plan by a field testing organization and its approval by NSF and EPA. Guidelines for this phase are described in Section 2 of this Protocol.

Verification Testing – This phase involves establishing the required test conditions, conducting the required tests, and the collection of the relevant data. Guidelines for this phase are described in Section 3 of this Protocol.

Data Assessment and Reporting – This last phase includes all data analysis and the preparation and dissemination of a Verification Report and Verification Statement. Guidelines for this phase are described in Section 4 of this Protocol.

# 2 Development of a Verification Test Plan

## 2.1 Purpose of a Test Plan

Prior to the start of verification testing of an induction mixer under the ETV Program, the field testing organization (FTO) shall prepare a Verification Test Plan that clearly describes how and by whom testing is to be conducted. An adequate Test Plan will help to ensure that testing is conducted and that the results are reported in a manner consistent the requirements specified in this Protocol. A good Test Plan also ensures that information about a vendor's mixer or series of mixers is available for incorporation into a Verification Report upon the completion of testing. An individual Test Plan should be developed for each mixer, or series of mixers, undergoing verification testing.

At a minimum a Test Plan for the verification of an induction mixer shall include:

- An introduction that briefly describes the objectives of verification testing and an overview of approach taken in this study;
- Roles and responsibilities of participants in the verification testing of the mixer;
- A complete description of the mixer(s) and its (their) intended functions and capabilities;
- A description of the site(s) where verification testing is to take place (i.e., the hydraulic laboratory)

- A description of the experimental design that includes the specific test procedures to be followed and identifies any necessary deviations from the requirements established in this Protocol;
- A description of the Quality Assurance/Quality Control procedures to be employed to ensure data quality objectives are met;
- A description of how data is to be analyzed, managed, and reported
- Health and safety procedures

Subsections 2.2 through 2.8 of this protocol establishes guidelines and requirements for the content and scope of each section required in a test plan.

## 2.2 Roles and Responsibilities of Involved Organizations

A Test Plan shall specify the names and addresses of each organization having a role in the verification of a mixer. Where possible, the Test Plan should include the names, titles, and contact information, for specific individuals with designated roles in the verification of the mixer. General guidelines on the roles and responsibilities for the primary participants are listed below.

### 2.2.1 NSF International

NSF is the US EPA's verification partner on the Wet Weather Flow Technologies Pilot. In the context of this Verification Protocol, NSF will select a qualified Testing Organization to develop and implement a Test Plan. In addition, NSF International has the following responsibilities:

- Review and approval of the Test Plan;
- Oversight of Quality Assurance, including the performance of technical system and data quality audits, as prescribed in the Quality Management Plan for the Wet Weather Flow Technologies ETV Pilot;
- Coordination of Verification Report peer reviews, including review by the Stakeholder Advisory Group and Technology Panel;
- Approval of Verification Report; and

- Preparation and dissemination of Verification Statement.

### 2.2.2 US Environmental Protection Agency (EPA)

The US EPA's National Risk Management Research Laboratory provides administrative, technical and quality assurance guidance and oversight on all WWF pilot activities. EPA personnel are responsible for the following:

- Review and approval of Test Plan;
- Review and approval of Verification Report;
- Review and approval of Verification Statement; and
- Posting of Verification Report and Statement on EPA Website.

### 2.2.3 Field Testing Organization

The Field Testing Organization (FTO) shall have experience with the use of high-rate induction mixers and also have experience with pilot testing and experimental design. The FTO will be the main consultant in charge of developing and implementing the Test Plan. The responsibilities of the FTO may include but are not limited to the following:

- Preparation of the site-specific Verification Test Plan, including its revision in response to comments made during the review period;
- Coordinating with the Manufacturer of the mixer;
- Contracting with the hydraulic laboratory, analytical laboratory, general contractor, and any other sub-consultants necessary for implementation of the approved Test Plan;
- Providing needed logistical support to the sub-consultants, as well as establishing a communication network, and scheduling and coordinating the activities for the verification testing;
- Overseeing or conducting the verification testing as per the approved Test Plan;
- Managing, evaluating, interpreting and reporting on data generated during the verification testing;
- Preparation and review of a Draft Verification Report.

### 2.2.4 Vendor

The vendor shall be a manufacturer of high-rate induction mixers. The vendor's responsibilities may include but are not limited to the following:

- Providing mixers and ancillary equipment required for the verification testing,
- Providing technical support for the installation and operation of the mixer; including the designation of at least one staff person as the point of contact;
- Providing descriptive details about the capabilities and intended function of the mixer;
- Review and approval of the Verification Test Plan prior to the start of testing;
- Review and comment on the Draft Verification Report and Verification Statement.

### 2.2.5 Hydraulic Laboratory

The hydraulic laboratory shall have experience with adjusting flume dimensions to provide flow rates required for the verification testing. Requirements for the facilities at the hydraulic laboratory are described in Section 2.4 of this Protocol. The hydraulic laboratory may or may not be owned and operated by the FTO. The responsibilities of the hydraulic laboratory may include but are not limited to the following:

- Providing flume(s) with the required dimensions.
- Providing process water to achieve the required flow rates.
- Measuring, evaluating and reporting on flow rates during the verification testing.
- Providing an electrical supply sufficient enough to supply the high-rate induction mixers and sampling equipment.
- Providing sampling rigs.
- Coordinating and taking the required samples. This also shall include transporting the samples to the analytical laboratory.
- Providing QA/QC documentation for flow rate and sampling.

#### 2.2.6 Analytical Laboratory

The analytical laboratory shall have experience measuring the dye or tracer chemical. The responsibilities of the analytical laboratory may include but are not limited to the following:

- Providing the instrumentation to measure the approved dye or tracer chemical.
- Coordinating and measuring the approved dye or tracer chemical.
- Measuring, evaluating and reporting on the dye or tracer chemical analyses.
- Providing QA/QC documentation for sample analysis.

#### 2.2.7 General Contractors

One or more general contractors may be needed for the installation of the induction mixer and ancillary equipment. The general contractor shall have experience with installing mixing devices in wastewater applications.

#### 2.2.8 Technology Panel on High-Rate Disinfection

The ETV Technology Panel on High-Rate Disinfection will serve as a technical and professional resource during all phases of the verification of a mixer, including the review of Test Plans and Verification Reports, as requested by NSF and EPA.

### 2.3 Capabilities and Description of the Equipment to be Tested

#### 2.3.1 Mixer Capabilities

The Test Plan shall identify the capabilities of the equipment to be evaluated in the verification testing. Statements should also be made regarding the application of the equipment, the known limitations of the equipment and what advantages it provides over alternative equipment.

Statements of capabilities that are too easily met may not be of interest to the potential user, while statements of capabilities that are overstated may not be achievable. The statement of capabilities forms the basis of the entire equipment verification testing and must be chosen carefully. Therefore the Test Plan should include a range of mixer sizes each tested in a range of flow velocities.

One obvious limitation of measuring dye or tracer chemical dispersion to verify mixer capabilities is that the energy of moving water is also responsible for some amount of dye or tracer chemical dispersion. This issue shall also be addressed in the statement of capability.

#### 2.3.2 Mixer Description

The Test Plan shall also include a description of the mixer(s), impeller configuration and ancillary equipment to be tested. Engineering drawings and photographs of the mixer(s), impeller configuration and ancillary equipment shall be included in the Test Plan. For each mixer, the impeller shall be commercially available and fully described in the Test Plan.

#### 2.3.3 Mixer Requirements

Data plates shall be permanently secured to each mixer. The data plates shall be easily read and contain a least the following information:

- Equipment name
- Model #
- Manufacturer’s name and address
- Electrical requirements-volts, amps, and hertz
- Serial number
- Warning and caution statements

### 2.4 Description and Requirements for Laboratory/Test Facility

#### 2.4.1 Test Plan Content

The Test Plan shall include a description of the testing facilities to be used in the Verification Tests, including the hydraulic and analytical laboratories. The Test Plan shall identify the channel design, flow control apparatus and all instrumentation to be used in creating, controlling and measuring flow and in conducting the dye/tracer dilution studies as required by Section 3 of this Protocol. Equipment descriptions shall include:

- Equipment name
- Model #
- Manufacturer's name

The Test Plan shall include diagrams showing the test facility, including location of the test mixer, hydraulic controls, dye/tracer injection points, sampling equipment, and other relevant equipment. Figure 1 provides a example of a verification test set-up.

### 2.4.2 Facility Requirements

Verification testing shall be conducted at a hydraulic laboratory that conforms to the criteria outlined below.

- The hydraulic laboratory shall have a defined channel, rectangular (preferred) or circular with a minimum width of 6 feet and water depth of 6 feet.
- The channel shall accommodate the installation of mixers and sampling equipment;
- The hydraulic laboratory shall be capable of creating and sustaining hydraulic conditions as specified in Table 1. The hydraulic laboratory shall be able to sustain flows ranging from 10 cfs to 120 cfs within the specified channel geometry. A calibrated flow control device such as a weir should control specific hydraulic conditions. This hydraulic control shall be far enough away from the mixer so that it does influence flow patterns in the vicinity of the mixer.
- The hydraulic laboratory shall be capable of supplying the specified electrical utilities for the mixers, dye or tracer feed pumps and sampling equipment. The hydraulic laboratory will also be required to measure amperage draw for each mixer during each test.
- The hydraulic laboratory shall be capable of creating constant hydraulic conditions during each mixer test using a water supply with characteristics that remain consistent throughout the tests and ensure conservation of the dye/tracer

chemical to be used. Flow shall be verified by use of the calibrated flow control device and independent flow / velocity measurements.

- The hydraulic laboratory shall be equipped with the necessary dye or conservative tracer chemical and associated equipment, and sampling equipment.

## 2.5 Experimental Design

The Test Plan shall completely describe the test procedures to be followed during the course of verification testing. The methods and procedures described in the test plan shall be consistent with the requirements and guidelines established in Section 3 of this Protocol. The Test Plan shall describe:

- how the required test conditions are to be achieved and maintained;
- the procedures for tracer/dye dilution study, injection, sampling and analysis; and
- procedures for data collection, storage, and compilation.

## 2.6 Quality Assurance Project Plan (QAPP)

The Test Plan shall include a QAPP that specifies procedures to be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the verification testing will provide sound analytical results that can serve as the basis for performance verification. The purpose of the QAPP is to ensure that data resulting from this verification testing is of known quality and that a sufficient number of critical measurements are taken.

### 2.6.1 Required Elements

The Quality Assurance Project Plan shall include the following elements:

- Description of methodology for measurement of accuracy for field and laboratory measurements.
- Description of methodology for measurement of precision for field and laboratory measurements.
- Outline of the procedure for determining samples to be analyzed in duplicate, the frequency and approximate number.
- Description of the procedures used to assure that the data are correct.
- Development of a corrective action plan.
- Provision of all QC information such as calibrations, blanks and reference samples in an appendix. All raw analytical data shall also be reported in an appendix.
- Provision of all data in hardcopy and electronic form in a common spreadsheet or database format.

The QAPP shall addess the following measurements/operations:

- Calibrating hydraulic control and flow monitoring
- Velocity distribution and flow monitoring
- Mixer Hp monitoring

- Induction unit flow rate monitoring
- Metering pump verification monitoring
- Preparation of dye or tracer chemical stock solution
- Preparation of dye or tracer chemical standards
- Fluorometer or other analyzer calibration
- Fluorometer or other analyzer operation
- Sampling rig operation

### 2.6.2 Quality Assurance Responsibilities

A number of individuals may be responsible for QA/QC throughout the verification testing. Primary responsibility for ensuring that both mixer and sampling and analysis activities comply with the QA/QC requirements of the Test Plan shall rest with the Testing Organization.

QA/QC activities for the analytical laboratory shall be the responsibility of that analytical laboratory's supervisor. If problems arise or any data appear unusual, they shall be thoroughly documented and corrective actions shall be implemented as specified in this section. The QA/QC measurements made by the analytical laboratory are dependent on the analytical methods being used.

### 2.6.3 Data Quality Indicators

The data obtained during the verification testing must be of sound quality for conclusions to be drawn on the equipment. For all measurement and monitoring activities conducted for equipment verification, the NSF and EPA require that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include four indicators of data quality: representativeness, accuracy, precision, and statistical uncertainty. The Test Plan shall include a plan for identifying such indictors.

#### 2.6.4 Operational Control Checks

The Test Plan shall describe the QC requirements that apply to the operation of the mixer equipment. This section will explain the methods to be used to check on the accuracy of equipment operating parameters and the frequency with which these quality control checks will be made.

#### 2.6.5 Data Reduction, Validation, and Reporting

The Test Plan shall include procedures to maintain good data quality. Specific procedures shall be followed during data reduction, validation, and reporting.

#### 2.6.6 System Inspections

On-site system inspections for sampling activities, field operations, and laboratories may be conducted as specified in the Test Plan. These inspections will be performed by NSF International or its designee to determine if the Verification Test Plan is being implemented as intended. At a minimum, NSF shall conduct one audit of the sampling activities, field operations program and laboratories during the Verification Test.

#### 2.6.7 Corrective Action

The Test Plan shall incorporate a corrective action plan. This plan shall establish acceptance limits and the corrective action to be initiated whenever such acceptance criteria are not met. The Test Plan shall identify the individuals responsible for implementation.

Routine corrective action may result from common monitoring activities, such as:

- Performance evaluation audits
- Technical systems audits

### 2.7 Data Management and Analysis

A variety of data will be generated during a verification testing. Each piece of data or information identified for collection in the Test Plan shall be included in the Verification

Report.  The data handling section of the Test Plan shall describe types of data to be collected and managed and how the data will be reported  the Verification Report.

All raw data and validated data shall be reported. These data shall be provided in hard copy and in electronic format. As with the data generated by the innovative equipment, the electronic copy of the laboratory data shall be provided in a spreadsheet. In addition to the sample results, all QA/QC summary forms must be provided.

Other items that must be provided include:

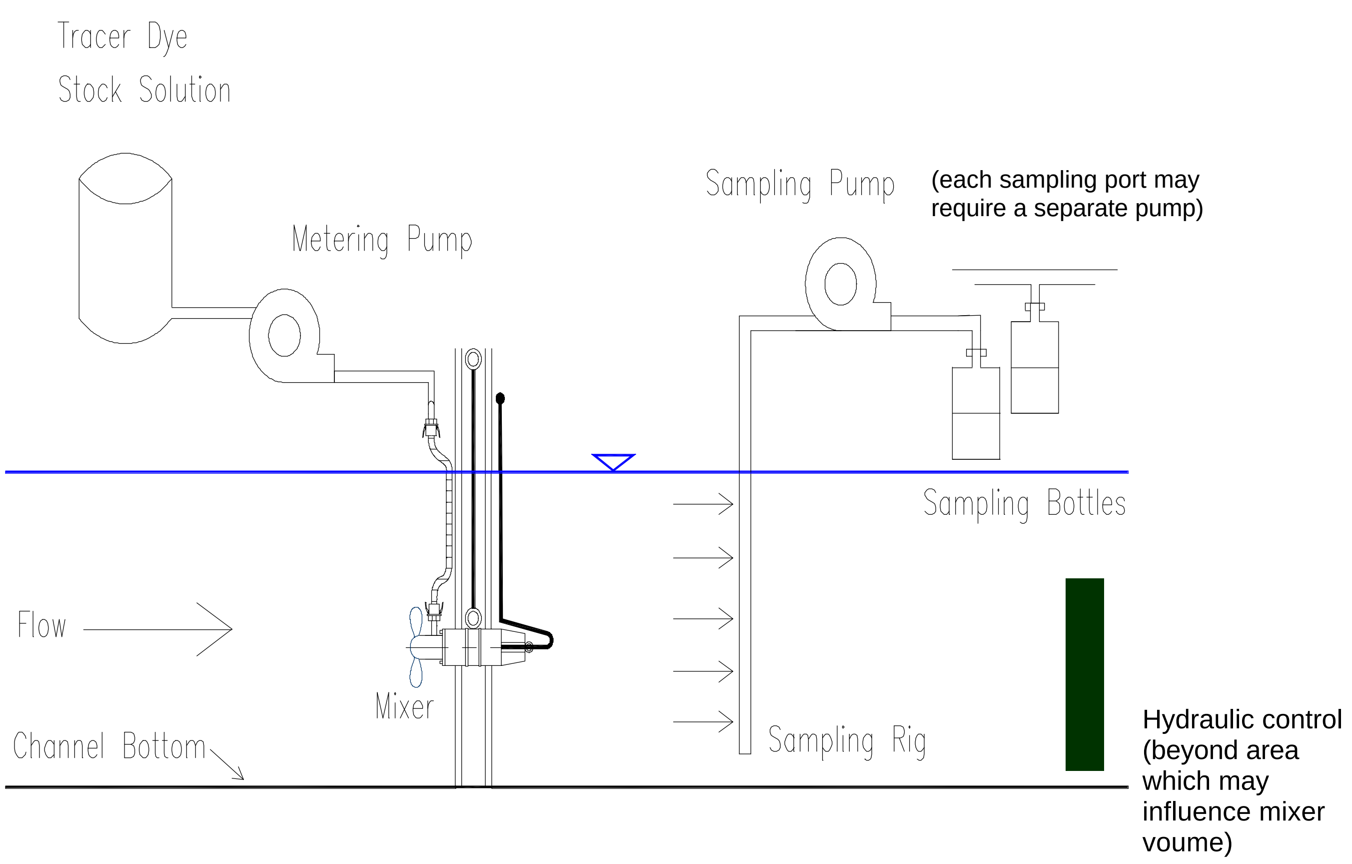
- field notebooks;
- photographs, slides and videotapes (copies);
- results from the use of other field analytical methods.

### 2.8 Safety Measures

The Test Plan shall address safety considerations that are appropriate for the testing laboratory and the equipment being tested.  The safety procedures shall address safety considerations, including the following as applicable:

- storage, handling, and disposal of dye or tracer chemical
- conformance with electrical code
- confined space entry
- working in and around a hydraulic conveyance system

**Figure 1- Example of Verification Test Set-up**



## 3 Verification Test Procedures- Requirements and Guidelines

This section contains requirements and guidelines to be followed by a Field Testing Organization in establishing site-specific test procedures for the verification testing of high-rate induction mixers. Test procedures developed by the Field Testing Organization in conformance with these requirements and guidelines should be clearly documented in a Verification Test Plan.

### 3.1 Test Objective

The objective of this test is to characterize the performance of a high-rate induction mixer with respect to its ability to rapidly transfer chemicals into a flowing body of process water. Mixer performance is characterized by the volume of water affected by a mixer (i.e., the size of its mixing zone) over a range of flow conditions that are representative of those observed in wet weather flow collection and treatment facilities.

### 3.2 Test Conditions

Each verification test shall evaluate a single induction mixer under the three sets of hydraulic conditions defined in Table 1. These hydraulic conditions are intended to represent the range of conditions typically encountered in wet-weather treatment facilities. The induction mixer manufacturer shall provide one mixer for each verification test. A verification test shall include the three hydraulic conditions defined in Table 1. It is recommended verification tests be performed on a series of induction mixers. For example a series of mixers may include, 2 Hp, 5 Hp, 10 Hp and 20 Hp mixers.

**Table 1 – Verification Test Hydraulic Test Conditions**

| Hydraulic Conditions | Velocity (fps) | Cross Section Flow Area ($ft^2$) | Sampling Distance[1] (ft) | Corresponding Sampling Time (sec) |
|---|---|---|---|---|
| Hydraulic Condition 1 | 0.5 | 36 | 5, 10, and 15 | 10, 20,and 30 |

| Hydraulic Conditions | Velocity (fps) | Cross Section Flow Area ($ft^2$) | Sampling Distance[1] (ft) | Corresponding Sampling Time (sec) |
|---|---|---|---|---|
| Hydraulic Condition 2 | 2 | 36 | 5, 10, and 15 | 2.5, 5.0,and 7.5 |
| Hydraulic Condition 3 | 3 | 36 | 5,10, and 15 | 1.7, 3.3, and 5.0 |

[1] Downstream distance from point of dye or tracer injection to point of dye or tracer sampling.

### 3.3 Methods and Materials

A single mixer shall be installed in the channel with one sampling rig set at the appropriate sampling location. The entire system, including channel flow, induction mixer, dye or chemical tracer metering pump, and sampling pump, shall be allowed to reach a steady state before sampling begins. These system components shall be monitored as specified in the QAPP, to assure and document that a steady state condition has been met. Once a steady state condition has been achieved, the sampling can begin.

Variability in the operation of the system should be minimized through the QA/QC procedure identified in the QAPP. However, the natural movement of water as it flows through the channel will introduce variability in data collected at the sampling rig. Therefore, it is recommended that an “event mean” type sample (i.e. flow weighted sample) be taken over a 30 minute sampling duration. Sampling pumps with constant flow rates should be used to take continuous samples for the duration of 30 minute. The total sample volume should not be less than two liters.

#### 3.3.1 Mixer Operation

The induction mixer will be operated as though it was being used for disinfection of wet-weather flows. However, instead of the induction unit mixing a disinfectant, such as sodium hypochlorite, it will mix water that is amended with a dye or conservative tracer chemical. The mixer will run continuously during the test. Amperage shall be measured for each mixer during each test.

### 3.3.2 Dye or Conservative Tracer Chemical

The dye or tracer chemical shall be a conservative material whose concentrations may accurately measured downstream of the mixer. The selection of the dye or tracer chemical shall be made with consideration of the water quality parameters of the process water. The use of Rhodamine WT is recommended be used for the testing because of the established standards associated with this chemical. The use of other conservative tracer chemicals such as LiCl may be proposed in the Test Plan.

The concentration of the dye or tracer at the sampling locations shall correspond with the detection limits of the dye or tracer analyzer. The concentration of the stock dye or tracer solution must be calculated based on mass balance and the appropriate dilutions.

### 3.3.3 Metering Pump

A chemical metering pump shall be used to inject the dye or tracer into the water that is drawn by the induction unit. The metering pump shall be sized to deliver the specified quantity of dye or tracer, based on the concentration of dye or tracer required in the process water, the process water flow, and the flow drawn by the induction unit.

The metering pump shall be operated for each of the hydraulic conditions during each verification testing. The metering pump shall draw from a stock solution of dye or tracer and discharge into the hose that conveys water to the induction unit.

### 3.3.4 Sampling Rig

A sampling apparatus or “rig” shall be constructed such that simultaneous water samples may be drawn at defined points across the entire cross section of the channel. The sampling rig will consist of a number of sampling ports spaced equally throughout the channel so to capture the complete cross sectional area. The sampling ports shall be spaced at a minimum of one port per square foot. The sampling rig shall be constructed so that a sample from each port can be drawn simultaneously. Each sample will be collected, bottled and analyzed individually. The sampling rig will require pumps to draw the process water from the sampling ports into sample containers.

The sampling rigs shall be located at five, ten and fifteen feet downstream of the mixer during each test run as defined in Table1. This corresponds to mixing times ranging from 2 seconds to 30 seconds.

Only one sampling rig shall be installed in the channel during each test run. Inactive sampling rigs left upstream of an active sampling rig may affect the mixing zone pattern.

#### 3.3.5 Fluorometer or other tracer analyzer

A fluorometer or tracer analyzer shall be used to measure the concentration of tracer in the process water. As a Rhodamine WT dye was previously recommended; it is recommended that a fluorometer be used to measure the concentration of the Rhodamine WT. In this case, an established company shall manufacture the fluorometer, and the procedures to be implemented for preparing and measuring the dye shall be established by the fluorometer manufacturer.

The fluorometer or other tracer analyzer will most likely be operated after the samples have been taken. It is recommended that the sample be analyzed after each hydraulic condition sampling period, so that corrections can be made to the sampling protocols.

#### 3.3.6 Velocity Meter

A velocity meter shall be used to verify the total flow and to calibrate to the hydraulic control. The velocity meter shall also be used to verify the velocity distribution within the channel.

### 3.4 General Test Procedures

### 3.4.1 Test Preparation

#### 3.4.1.1 Standards

Tracer chemical standards shall be used to calibrate the fluorometer or other tracer analyzer. These standards shall be made according to a method developed by the manufacturer of the fluorometer.

#### 3.4.1.2 Fluorometer or other analyzer calibration

The analyzer shall be calibrated according to a method developed by the manufacturer. An approved QA/QC plan shall be used.

#### 3.4.1.3 Metering pump calibration

The metering pump that injects dye or tracer chemical into the induction flow shall be calibrated prior to testing. The delivery rate shall be verified volumetrically.

### 3.4.2 Test Conditions

#### 3.4.2.1 Flow

During testing the flow in the channel shall be measured. Once the flow has been verified, flow can be estimated using the hydraulic control. Flow shall be controlled to create the specified velocities as defined in Table 1, within the given channel geometry.

#### 3.4.2.2 Channel geometry

The hydraulic laboratory shall establish the channel geometry prior to testing. The channel shall have a minimum cross sectional width of 6 feet and a minimum water depth of 6 feet.

#### 3.4.2.3 Mixer size

The vendor shall establish the mixer size (Hp) prior to the test. Hp shall be verified and documented in the field by measuring the amperage, and calculating wattage by the following equation;

$$\text{Watts} = \text{amperes} \times \text{voltage}$$

Note: 746 watts is the electrical equivalent to one (1) horsepower.

### 3.4.3 Mixer Testing

#### 3.4.3.1 Sampling Locations

Each mixer shall be tested under three hydraulic conditions as defined in Table 1. During each hydraulic condition, dilution samples shall be collected separately at locations 5, 10 and 15 feet downstream of the mixer (or at the equivalent contact time based on velocities presented in Table 1). This will provide information with respect to the shape of the mixing zone. Only one sampling rig shall be installed in the channel during each test run.

#### 3.4.3.2 Sampling procedures

The sampling rig shall have sampling ports evenly spaced throughout the channel. Samples shall be simultaneously drawn from each sampling port into individual sample bottles. Drawing the samples simultaneously will likely require having a dedicated pump for each sampling port.

Sampling at each location shall occur separately. The sampling rig should be installed at one sampling location, the samples taken, and the rig removed. The sampling rig should then be installed at the next sampling location and the same procedure followed.

### 3.4.4 Tracer Analysis

#### 3.4.4.1 Sample handling

Samples shall be collected in approved bottles, preserved by an approved method and analyzed before the approved maximum holding time.

#### 3.4.4.2 Analyzer procedures

The fluorometer or other tracer analyzer shall be used to the specification of the manufacturer. An approved QA/QC program shall be implemented.

### 3.5 Data Analysis

The Test Plan shall describe the procedures used to define the mixing zone volume based on the concentration of dye or tracer chemical in the process water throughout the mixing channel. The measured dye or tracer concentration shall be used to generate an isopleth diagram as depicted in Figure 2. An isopleth diagram shall be generated for each hydraulic condition and downstream sampling distance defined in Table 1 for a total of nine isopleth drawings for each mixer tested.

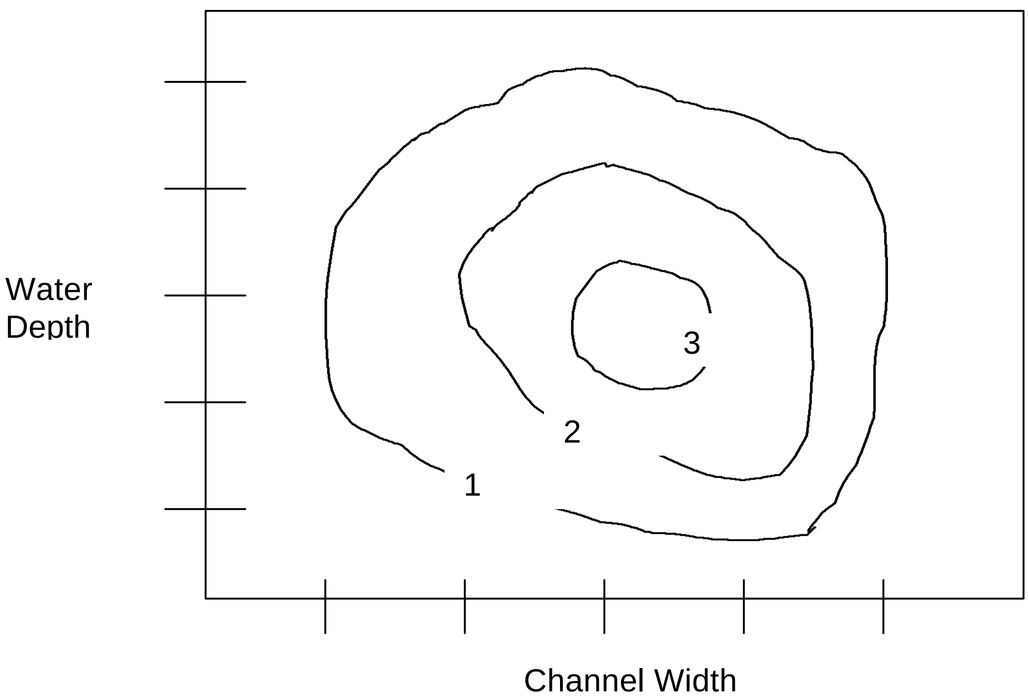
The isopleth diagrams shall be drawn to depict the uniform dye or tracer concentration. The uniform theoretical dye or tracer concentration shall be defined by the concentration if the dye or tracer were instantaneously dispersed over the entire cross section of the channel. It shall be calculated by the following equation:

$$\text{Uniform Tracer Concentration} = \frac{(\text{Tracer Stock Concentration} * \text{Metering Pump Feed Rate})}{\text{Process Water Flow Rate}}$$

The uniform theoretical dye or tracer concentration shall be represented by the value of 1.0. Tracer concentrations greater than the uniform dye or tracer concentration shall represented by values greater than 1.0, as depicted in Figure 2.

**Figure 2- Tracer Concentration Isopleth Diagram**

A percent mix factor shall be calculated once the uniform theoretical dye or tracer concentration isopleth has been established. The percent mix factor represents the area of the channel that has experienced a complete mix. The percent mix factor shall be calculated by the following equation:




$$\text{Percent Mix Factor} = \frac{\text{Channel Area with Tracer Concentration Greater than Uniform Concentration}}{\text{Total Channel Cross Section Area}}$$

Other data that shall be collected are process water flow velocity, mixer amperage draw, and dye or tracer feed pump rate. Results shall be presented in tables and figures.

# 4 Reporting

## 4.1 Data Management and Analysis

A variety of data will be generated during a verification testing. Each piece of data or information identified for collection in the Test Plan will need to be provided in the Final Verification Report. The data handling section of the Test Plan shall describe what types of data and information needs to be collected and managed, and shall also describe how the data will be reported to the NSF for evaluation.

## 4.2 Verification Report

The FTO shall prepare a draft Verification Report describing the verification testing that was carried out and the results of that testing. The Verification report shall undergo a complete review by NSF International and the EPA, as well as a peer review as recommended by the Technology Panel on High Rate Disinfection. The mixer vendor shall review and be provided the opportunity for input on its content. This report should fully describe the mixer and the verification of its performance characteristics. At a minimum, shall include the following items:

- Introduction
- Executive Summary
- Description and Identification of Product Tested
- Procedures and Methods Used in Testing
- Results and Discussion
- Conclusions and Recommendations
- References
- Appendices, which may include test data.

## 4.3 Verification Statement

NSF and EPA shall prepare a Verification Statement that briefly summarizes the Verification Report for issuance to the mixer vendor. The Verification Statement shall provide a brief description of the testing conducted and a synopsis of the performance results. The Statement is intended to provide verified vendors a tool by which to promote the strengths and benefits of their product.

# 5 References


EPA. 1973. Collins HF and Kruse (EPA-670/2-73-077). United States Environmental Protection Agency.

Moffa & Associates. 1997. *CSO Final Disinfection Pilot Study Final Report*. Spring Creek AWPCP Upgrade Capital Project No. WP-225. Camp, Dresser & McKee. November 1997.

White, Clifford Geo. 1992. *Handbook of Chlorination and Alternative Disinfectants, 3rd edition.* Van Nostrand Reinhold, New York. 1308 pp.

## 6 Glossary

Terms and acronyms used in this Protocol that have special meaning are defined here.

**Complete Mix** – The dispersion of dye or tracer chemical resulting in an equal concentration distribution throughout the channel. This is represented by the unit isopleth (i.e. isopleth equal to 1.0).

**Dye or Tracer Chemical** - A conservative chemical material that can be measured in water. A conservative chemical does not react or change form when diluted in water.

**EPA** - The United States Environmental Protection Agency, its staff or authorized representatives.

**Event Mean Sample** – A flow weighted composite sample taken throughout an event. This sample represents the average concentration throughout the sampling duration.

**Field Testing Organization** – An organization qualified to conduct studies and testing of induction mixers in accordance with the Verification Protocol.

**Induction Mixer** – A mechanical mixer that was designed with a vacuum port at the impellor. The mixer impellor rotates at 35,000 rpms or greater and causes a vacuum at this port. This vacuum draws disinfectant chemical to the impellor where it is mixed with the process water.

**Isopleth** – A line connecting points of equal dye or conservative tracer concentrations.

**Mixing** – The act of creating turbulence within a flow path for the purpose of dispersing chemical.

**NSF** – NSF International, its staff, or other authorized representatives.

**Percent Mixing Factor** – the area of the channel that has experienced a complete mix divided by the total area of the channel.

**Quality Assurance Project Plan (QAPP)** – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project. The QAPP is a required component of a verification Test Plan.

**Representativeness** - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point or for a process conditions or environmental condition.

**Sampling Rig** – A rigid device used to keep the sampling ports at specified locations within the channel.

**Test Condition** – A specific mixer horsepower, sampling rig location, and channel flow velocity.

**Verification** – To establish the evidence on the range of performance of equipment and/or device under specific conditions following an established protocol(s) and test plan(s).

**Verification Protocol** – a written document that clearly states the objectives, goals, and scope of the testing under the ETV Program and that establishes the minimum requirements for verification testing and for the development of a verification test plan. A protocol shall be used for reference during Manufacturer participation in the verification testing program. Often simply referred to as a Protocol.

**Verification Test Plan** – A written document that establishes the detailed test procedures for verifying the performance of a specific technology. It also defines the roles of the specific parties involved in the testing and contains instructions for sample and data collection, sample handling and preservation, and quality assurance and quality control requirements relevant to a given test site.

**Verification Report** – a written document prepared by the FTO containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results.

**Verification Statement** – A written document that summarizes a final report reviewed and approved by NSF on behalf of EPA or directly by EPA.

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